August 15, 2002

PLASTICS WHITE PAPER

Volume 2

Polystyrene Plastics Report

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Optimizing

Plastics Use,

Recycling, and

Disposal in

California

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NewPoint Group®
Management Consultants

August 15, 2002

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Polystyrene Plastics Report

Optimizing Plastics Use, Recycling, and Disposal in California

Prepared for:

INTEGRATED WASTE MANAGEMENT BOARD

CALIFORNIA CONSERVATION

California Integrated Waste Mangement Board

California Department of Conservation

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Guide to Four Volume Report

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Why a Plastics White Paper?
Why are California Plastic Policies Not Working?
What Should the State Do About Plastics?

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SB 1127 Polystyrene Status Report

SB 1127, sponsored by Senator Karnette, was signed by the governor in September, 2001. The bill requires the California Integrated Waste Management Board (CIWMB) to conduct a study, by January 1, 2003, on the use and disposal of polystyrene (PS) in California, and to report to the Governor and Legislature on the findings and recommendations made by the study. Specifically, the report is to do the following:

1. Analyze how polystyrene, including, but not limited to, food service and transport packaging, is being used by consumers before it enters the waste stream, the amount of polystyrene being landfilled annually in the state, the amount being reused and recycled, and the related environmental and public health implications, if any.
2. Recommend methods for source reducing, reusing, and recycling, and for diverting polystyrene from the state's landfills.
3. Address the cost of the disposal of polystyrene in volume and weight terms.
4. Examine and identify current and potential markets for recycled polystyrene products.

This volume of the plastics white paper fulfills these requirements. Concurrent to the legislative process for SB 1127, the CIWMB and Department of Conservation (DOC) initiated a plastics white paper project to define current California plastics issues and provide a menu of policy options for the CIWMB and the DOC. The State is interested in: (1) increasing the plastics recycling rate, (2) increasing the use of recycled plastics, and (3) promoting plastics resource conservation. After SB 1127 was signed into law, CIWMB staff incorporated this polystyrene status report into the plastics white paper project. This volume fulfills requirements of the SB 1127 report, while also providing a broader plastics white paper perspective on how polystyrene issues fit into the universe of plastics.

The language within SB 1127 does not fully identify an impetus behind the bill. Several cities in Senator Karnette's district, within Los Angeles County, approached the Senator in 2001 with the idea of a "source control" bill for polystyrene food containers.[1] As a result of new water quality requirements, these cities were concerned about disposable cups and food packaging entering their storm drain systems. In March 2001, the Los Angeles Regional Water Quality Control Board (LARWQCB) developed a total maximum daily load (TMDL) for trash in the Los Angeles Basin River Watershed.[2] This TMDL, which was finalized in September 2001, requires the reduction of trash in the waterways by 10 percent a year, to a zero tolerance level within 13 years. It is designed to attain the water quality standards for trash in the Los Angeles River watershed.[3]

To comply with the TMDL, some cities in the region are examining a range of options, including placing traps, screens, and/or filters on Los Angeles County's 800,000 storm drain catch basins. These control options could cost cities and the county an estimated $100 to $400 million in capital infrastructure, and a similar order of magnitude in operating and maintenance expenditures, over the next 12 years. Because some cities felt that polystyrene was a major component of trash in the Los Angeles River, and that it is very difficult and costly to remove, they originally proposed to Senator Karnette a bill that would phase-out the sale of polystyrene drink and fast food containers over a ten year period (with substitution of paper and other water soluble products over that period). That bill eventually was amended to this study bill. There was no mention in the SB 1127 legislation of the storm water problem, TMDL requirements, or the high potential costs faced by the cities in complying with the regulatory requirement.

Stakeholder Input to Ploystyrene Status Report

As part of the broader plastics white paper effort, stakeholders have had several opportunities to provide input to this polystyrene plastics report. This volume reflects the wide range of input and information received during this plastics white paper project. A framing session on polystyrene plastics was held at the CIWMB in December 2001. In addition, stakeholders provided written input in March 2002, in response to a letter soliciting input. Stakeholders also provided input at the June 24 and 25, 2002 Plastics White Paper Workshop, at a follow-up meeting on polystyrene held on July 25, 2002, and during a conference call to discuss PS technical issues on August 6, 2002. The polystyrene industry provided a significant amount of information and comments (included in volume 4 of the plastics white paper).

While this report fulfills requirements of SB 1127, it is only the first step in helping address concerns of the cities and the polystyrene industry. The report provides background information on polystyrene uses, disposal, recycling, markets, and impacts, as well as recommendations for further action. With the July 25, 2002 polystyrene meeting, the CIWMB and stakeholders have already initiated a process to help address many of the issues raised during development of this report.

Polystyrene Use

There are many types of polystyrene and a wide range of uses. The two major types of polystyrene are crystal (or solid) polystyrene and rubber-modified polystyrene. Crystal PS comes in two forms, the hard, clear form seen in salad clam shells, or the more familiar form of PS, the white material used in cups and molded packaging, called foamed or expanded polystyrene (EPS). Rubber-modified PS, which is typically opaque or colored, has an elastomer, typically polybutadiene rubber, attached to enhance impact strength. About 57 percent of the polystyrene consumption in the U.S. in 1999 was crystal, while the remaining was rubber-modified.[4] Exhibit 1 illustrates the percentages for types and production methods of PS.[5] Table 1 describes characteristics of five types of PS and typical products for each of the major types and production methods.

Exhibit 1
Polystyrene Types and Production Methods

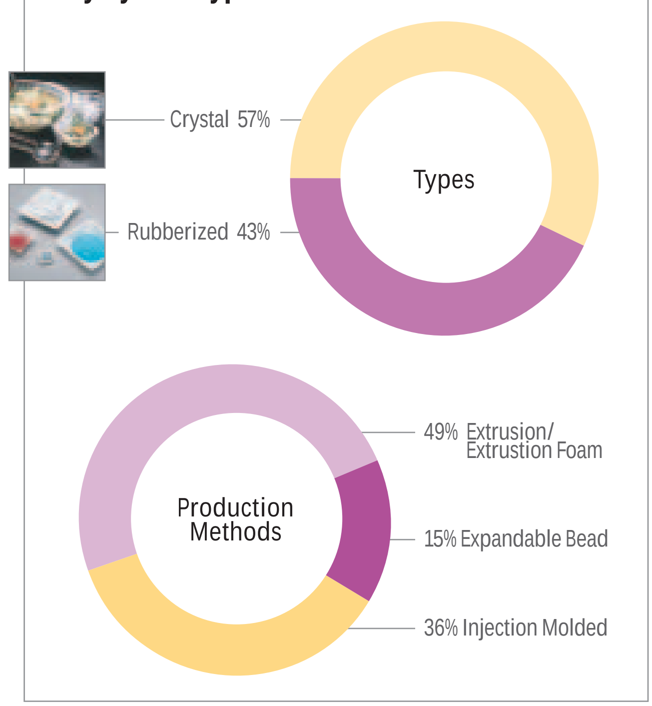
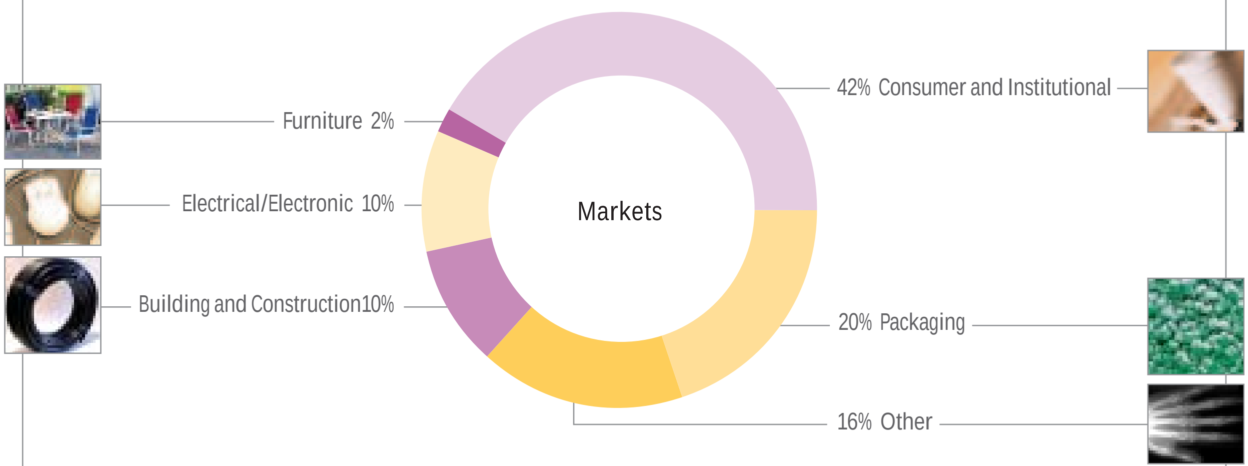


Table 1
Polystyrene Types and Typical Products[8]

Polystyrene Type	Description	Typical Products
Crystal (rigid)	Transparent, can be injection molded or extruded, rigid, good clarity and stiffness	Audio equipment, dust covers, clear audio tape cassette, and CD jewel cases; office supplies, computer disk reels, tumblers, flatware, housewares, display cases, petri dishes, pipettes, bottles
Impact (rubberized)	Opaque, higher strength, less clarity and stiffness than crystal PS	Electronic appliance cabinets, business machine housings, video cassettes, small appliances, smoke detectors, furniture, refrigerator door liners, luggage, horticulture trays, dairy and yogurt containers
Non-foamed PS sheet	Extruded or oriented, melted plastic is forced through a flat-faced die, extruded sheet is then thermoformed. Can use impact PS or crystal PS (for clear)	Glazing, decorative panels, cookie trays, document wrap, blister pack, salad containers, lids, plates and bowls
Foamed PS sheet	Extruded, thermoformed, made by extruding crystal PS with a nucleating agent and a foaming agent (usually pentane), material is extruded through an annular die and foamed as the material exits the die, sheet thickness and density is varied to meet end-use requirements, has excellent thermal insulation qualities	Egg cartons, meat and poultry trays, food service trays, fast food packaging, insulation, protective covers for glass bottles, plates, hinged containers, cups
Expanded PS (EPS)	Made from PS resin granules impregnated with a blowing agent (typically pentane). Expanding beads fuse together to form the finished product, white in color, 90 to 95 percent air (99.6 percent for loose fill). Small beads are used for cups and containers, medium beads for shape-molded packaging, and large beads for the expanded loose-fill packaging (peanuts), insulates, light weight, resists moisture	Insulation board, molds for metal castings, flotation devices, packaging (molded shapes, peanuts), cups, and containers

There are four major production methods for PS: extrusion, extrusion foam, injection molded, and expandable bead. Extrusion PS includes agricultural trays, clamshells, meat trays, dairy containers, and decorative panels. Molded PS products include products such as appliance housings, CD jewel cases, tumblers, flatware, and some EPS packaging. Expanded PS includes cups, shape-molded packaging, and packaging peanuts. Exhibit 2 illustrates the percent of PS used in each of six major markets. Consumer and institutional products, including PS food service, is the largest category, with 42 percent of the total, with packaging second, at 20 percent of the total use.[6] The packaging and disposable share, as estimated from previous studies, is 44 percent of total production.[7]

Exhibit 2
Major Markets for Polystyrene



Polystyrene sales in the US have increased from about 5 billion pounds in 1990, to over 6 billion pounds in 2001, as shown in Exhibit 3.[9] PS production was about 6 percent of all plastic production in 2001, and 7.6 percent of total thermoplastics (i.e. of the seven major resin types).

California production figures for PS must be estimated from national figures, as there is no data collected specifically for states. Table 2 illustrates the estimated California share of PS sales, calculated based on population. The total California share of PS production and sales are an estimated 377,579 tons. Applying the market share information to the California estimate, 77,006 tons are packaging, and 156,829 tons are consumer/institutional applications. The packaging, and disposable share for California was an estimated 166,135 tons in 2001.

According to the American Foam Packaging Recyclers Association, there are sixteen manufacturers of EPS foam packaging in California operating at 22 locations. These facilities use an estimated 22 to 26 million pounds of resin per year (11,000 to 13,000 tons), and employ over 1,000.

Exhibit 3
U.S. Polystyrene Production Over Time
Tons Per Year

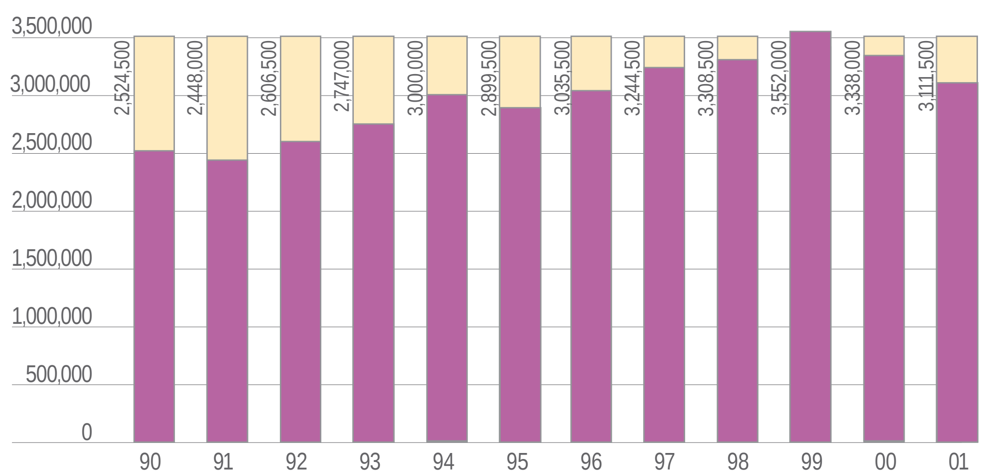


Table 2
Estimated California Share of PS Production

Market	Tons
Packaging	77,006
Building and Construction	36,249
Electrical and Electronics	37,376
Furniture	5,885
Consumer and Institutional	156,829
Other	64,234
Total	377,579

Polystyrene Recycling

Post-consumer polystyrene recycling efforts began nationally in 1989, although manufacturers have been recycling post-industrial PS in their facilities since the 1970s. In the late 1980s, in response to growing consumer pressure and concern about landfill space, the PS industry initiated post-consumer recycling programs. Industry established the National Polystyrene Recycling Company (NPRC) to recycle PS food service and molded packaging. The NPRC was a $16 million start-up effort between eight corporations, including Amoco, ARCO, Chevron, Dow Chemical, and Mobil. Initially, the NPRC had five plants in Boston, Los Angeles (Corona), San Francisco, Chicago, and Philadelphia. Another affiliated facility was located in Portland. The industry was initially targeting a 25 percent recycling goal for food service and packaging PS. The Corona, California plant was the last of the facilities still operating. It finally closed in late 2000, unable to make the operation economically successful. *Plastics Recycling Update* reported that the plant was operating at 30 to 35 percent of its 15 million pound capacity due to the lack of sufficient supply. The decision to close the plant was "strictly economic."[10]

Food Service and Other Recycling

The NPRC effort, particularly as it relates to food service PS recycling, was unsuccessful for a number of reasons. While technically feasible, PS recycling is not economical because of contamination, transportation (due to its light weight), and collection difficulties. The NPRC reportedly lost $85 million running the recycling facilities between 1989 and 1997.[11] Industry found that there was reluctance among organizations, businesses, and consumers to collect PS for recycling. Like many other resin types, it was also difficult for the recycled resin to compete with virgin PS, which is often available for a lower or similar cost per pound. In addition, PS from food service applications also had problems due to odors and color in the recycled resin. Curbside recycling of PS is not economical at this time because the material collected is readily contaminated, making it costly to handle and difficult to find markets.

Despite these problems, there is still a limited amount of food service PS recycling, primarily through institutions, although there is none in California at this time. In 1999, 6.5 million pounds of food service PS was recycled nationwide, dropping to 4.5 million pounds in 2000. Dart Container, based in Michigan, does a limited amount of food service recycling through institutions near their facilities. For several years, Dart operated a program whereby major users could lease a densifier for $295 per month, and collect and densify food service EPS, which Dart would backhaul for recycling.[12] There were a number of participants in California at one time, but none now. According to the company, customers were not willing to pay for the densifier or allocate the labor necessary to sort and process the material.

While this food service effort was not successful, there are several established recycling programs for PS. There are three primary categories of materials recycled. Transport packaging (EPS) is collected at manufacturing facilities across the US, including 15 in California. Loose fill packaging is also collected at these facilities, as well as at packaging and mailbox locations across the country, including over 375 in California. Thirdly, a variety of non-foam PS products such as CD cases, video cassettes, and agricultural trays are recycled. In addition, there is still a small amount of PS food container recycling from some institutional locations, as well as post-industrial PS recycling.

Exhibit 4
National EPS Post-Consumer Recycling Rates and Quantities
Millions of Pounds

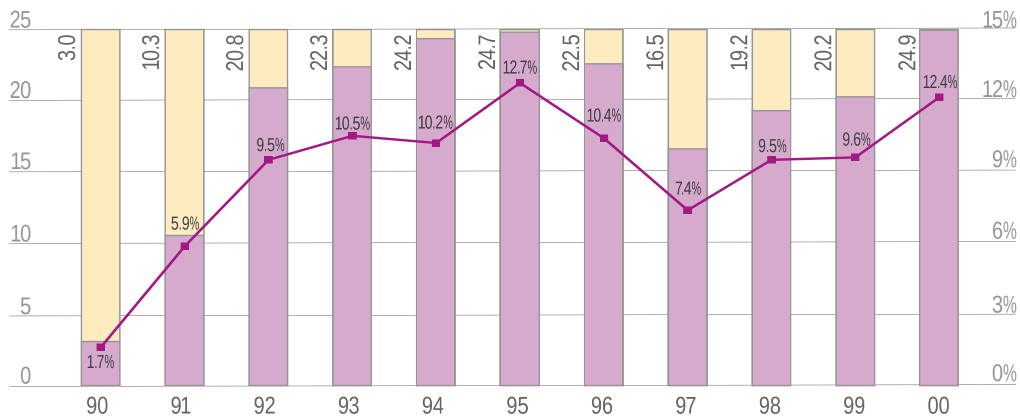


Table 3
National PS Post-Consumer Recycled
(Millions of Pounds)

PS Type	1999	2000	Recycling Rate (2000)
Bottles & Containers	0.2	0.2	0.1%
Protective Packaging	20.2	24.9	12.4%
Food Service Packaging	6.5	4.5	0.2%
Other Applications	20.5	22.7	0.6%
Total Recycled	**47.4**	**52.3**	**0.8%**

National PS recycling quantities are shown in Exhibit 4 and Table 3.[13] Table 4 illustrates the California share (by population) of PS recycled.[14] These estimates may be conservative, as California likely has higher than proportional PS recycling due to the larger number of EPS recycling facilities statewide. Table 5 illustrates typical recycling costs as compared to recycled and virgin resin prices.[15] There is little margin between recycled resin prices and recycling costs.

EPS Protective Packaging Recycling

The Alliance of Foam Packaging Recyclers (AFPR), a trade association of over 80 EPS protective packaging manufacturers, equipment manufacturers, and resin suppliers, was established in 1991 to help support foam packaging recycling. There are over 110 member plant locations nationwide that collect EPS, as well as many other non-member locations (such as loose fill manufacturers). The AFPR also has a mail-back program, and will accept EPS packaging that is sent to them by consumers.

Most EPS recycling in California (and nationwide) occurs through EPS manufacturing facilities. There are fifteen facilities in California that accept EPS packaging, as shown in Table 6.[16] These facilities provide take-back, primarily of molded EPS packaging, with an estimated recycling rate of 19 to 23 percent, significantly higher than the national rate of 12 percent. California EPS manufacturers collected an estimated 5 million pounds of post-consumer EPS in 2000, again significantly more than the estimated California share.[17]

Table 4
California PS Production and Recycling Estimates, 2001

	CA Tons Produced	Recycling Rate	Tons Recycled	Millions of Pounds Recycled
Bottles & Containers	7,552	0.1%	6	0.01
Protective Packaging	11,327	12.4%	1,405	2.81
Food Service Packaging	154,808	0.2%	310	0.62
Other Applications	203,893	0.6%	1,223	2.45
	377,580	**0.8%**	**2,944**	**5.89**

Table 5
Typical PS Recycling Costs and Resin Prices

Type of PS Recycling	Cost or Price per Pound (Dollars)
Food Service Recycling Cost	$.10 to .50
EPS Packaging Recycling Cost	$.20 to .35
Recycled Resin Price	$.38 to .45
Virgin Resin Price	$.40 to .70

Most EPS packaging is returned from larger manufacturers and distribution centers such as furniture and automobile manufacturers. Ethan Allen is operating a collection system that incorporates 300 stores and 26 distribution centers (two are in California). To make the program economical, trucks backhaul EPS to the distribution centers, where it is collected and sent to a manufacturing facility. There is a 100-mile radius within which it is economical to transport loose EPS on a truck. If a backhaul vehicle is not available, costs range from $85 to $450 per shipment. Larger manufacturers can densify the PS before shipping it to reduce costs. EPS collection programs from retailers are limited. Retailers are resistant to establishing collection systems, even with EPS industry support, because they do not want to give up valuable warehouse or parking lot spaces.

Table 6
EPS Packaging Collection Sites in California

	Company	Location
1	Astrofoam Molding	Camarillo
2	Foam Fabricators	Modesto
3	Foam Fabricators	Compton
4	FP International	Commerce
5	FP International	Redwood City
6	Many Hands Recycling, Inc.	Pittsburg
7	Marko Foam Products, Inc.	Corona
8	Pacific Molded Foam	Downey
9	Storopack, Inc.	Downey
10	Storopack, Inc.	Anaheim
11	Storopack, Inc.	San Jose
12	Styrotek, Inc.	Delano
13	Topper Plastics	Covina
14	Tuscarora Incorporated	Hayward
15	U.S. Foam	Compton

There are a few local government drop-off programs for EPS. EPS manufacturer FP International supports drop-off facilities in Palo Alto and San Mateo County. Contamination is more of an issue with these programs than the manufacturer take-back systems. Standards for EPS recycling are quite high – manufacturers require material that is not contaminated with adhesives, film plastic, cardboard, dirt, etc. Generally, materials that have been collected through a curbside program, or even left in a drop-off bin or outside in a storage yard, are likely to be too contaminated for end-users. This limits the amount of EPS material that can be recycled. Like other plastics recycling, the key to successful EPS recycling is obtaining sufficient quantities of clean material. Generally, curbside programs are not able to generate adequate quantities, or quality, for use by EPS manufacturers. Because of contamination issues, conversion technologies, discussed in Volume I, appear to be one potential alternative for diverting PS that is not readily recyclable.

Loose Fill Packaging Recycling and Reuse

A second major area of PS recycling and reuse is loose fill packaging, or peanuts. In 1991, the nation's four major EPS loose fill manufacturers established the Plastic Loose Fill Council (PLFC).[18] The program was established in part because of environmental concern by loose fill customers, such as mail order companies. Two of these companies, FP International and Storopack, Inc. operate plants that produce and recycle EPS loose fill in California. Locations include Redwood City and Commerce (FPI); and Anaheim, Downey, and San Jose (Storpack). Industry has invested $650,000 in the program since its inception in 1991.[19]

The PLFC operates a national, manufacturer-sponsored post-consumer EPS packaging take-back program. The program provides a toll-free Peanut Hotline (800-282-2214) to provide callers with the nearest location that accepts loose fill packaging for reuse. The hotline receives about 5,000 calls a month. In addition, over 200 mail order and other companies include a flier in their packaging with information on the program, and many communities list information on the program in recycling guides. Over 375 locations in California, and over 1,500 nationwide, participate in the program. Take-back locations primarily include Mail Boxes Etc. and other similar packaging stores.

The program has broad benefits to all participants. Collection sites provide improved customer service and are able to reduce their purchase of new packaging peanuts by 50 percent by reusing returned peanuts. Industry reuse of peanuts is estimated at 30 percent of the 45 million pounds of loose fill manufactured each year. The overall reuse rate for EPS in California is estimated at between 20 and 30 percent, a total of about 1 million pounds per year (500 tons).

Other types of PS recycling make up about 43 percent of the total PS recycled. Materials recycled include insulation board, audio and VHS cassettes, CD jewel boxes, and nursery trays and containers. Most of these materials are recycled through commercial sources, not curbside programs.

Polystyrene Markets

There are several markets for PS, both closed- and open-loop recycling, and there appear to be sufficient end-markets for all the clean PS that can be collected. Almost half of the EPS packaging recycled is remanufactured back into EPS packaging – both molded and loose fill. Other applications for EPS recycling include building applications such as siding and deck board, ceiling texture, molding, electronic products, auto products, agricultural products, office supplies, egg cartons, and bean bag filler. Markets for non-foam PS include coat hangers, picture frames, waste paper baskets, video cassettes, flower pots, and nursery trays.

Companies that produce non-foam rigid PS products consume about 25 percent of the EPS packaging recycled, EPS molders consume about 50 percent, and loose fill manufacturers purchase the remaining 25 percent. The amount of material currently available limits the recycled content level in molded EPS to about 2 percent post-consumer material, overall.[20]

Recycled content levels in EPS molded packaging can be as high as 25 percent, but typically are much lower.[21] These levels could increase in the future, as one manufacturer of EPS recycling equipment recently obtained acceptable ASTM standards with EPS made with 20 percent and 40 percent regrind (recycled content).[22] Applications with higher cushioning needs should use a lower recycled content level.

Molders typically incorporate recycled content into their products by blending in used expanded beads from products they take in and grind down to bead levels.[23] Because the recycled EPS is not re-blown, it has a different shape, and can only be used in limited quantities. This material serves primarily as "dead filler" material because it lacks blowing agent. Due to design restrictions, molded EPS, especially thin material, can tolerate 5 to 10 percent recycled EPS without a loss in quality characteristics. Less demanding applications such as EPS block manufacturing, can tolerate higher levels.

Another primary market for recycled EPS molded packaging is in the production of loose fill. Loose fill manufacturers are active in EPS collection programs, and loose fill typically ranges from 25 percent to 100 percent recycled content. Not all of this is post-consumer, but over 65 percent of the EPS recycled by one California manufacturer is post-consumer. If loose fill continues to be reused in the take-back program, material could potentially be diverted from the landfill for many cycles of use.

There are also a number of markets for PS in the building and construction industry, including several companies located in California. Rastra Building Systems produces a concrete form made of 85 percent recycled polystyrene. There are two locations in California, and the material can be transported up to 400 miles economically. The facility has capacity for 312,000 pounds per year. Timbron, a Stockton based company (that received a $1 million Recycling Market Development Zone loan from the CIWMB in 1999), densifies EPS to produce interior moldings and other similar products that can be sawed and nailed like wood. Timbron products are sold at Home Depot stores. EPS constitutes 75 percent of their finished products, with demand at over 18 million pounds annually. Timbron provides large suppliers of recycled EPS with a $60,000 densifier as well as support for labor in collecting and densifying the material. Suppliers include HP, Epson, Sony, Panasonic, Marko Foam Products, and Tatung America. Timbron uses both post-consumer and post-industrial EPS.

Polystyrene Disposal

In 1999, an estimated 300,000 tons or over 3 million cubic yards of PS were landfilled in California.[24] This amount is relatively small in terms of overall waste generation, only 0.8 percent of the total waste landfilled in California. Even considering volume rather than weight, PS in the waste stream does not appear to pose significant problems related to landfill capacity.

PS disposal is no different than any other material. If it is not recycled, users dispose of their PS with other solid wastes. One unique issue with EPS is that it is very bulky, so for example consumers that purchase a new appliance with EPS protective packaging can fill a trash can with foam that week. Another potential issue with PS disposal, discussed below, results when fast food containers (cups, plates, clamshells) either spill over from trash receptacles or blow out of trash receptacles. Because the EPS material is so light, it can blow away and can enter waterways.

The cost of PS disposal can be calculated from typical disposal costs figures, as it will be collected with other solid waste from both commercial and residential sources. Typical solid waste collection costs in California are $100 per ton, including collection and an average tipping fee of $30 per ton. Total disposal costs for PS are thus estimated to be about $30 million per year.[25] These costs are covered through solid waste fees paid by residential and commercial users, like all other solid wastes.

Because of its light weight, PS products tend to be significantly source reduced, and thus lead to significantly lower landfill tonnage than substitute products. For example, a PS foam cup weights about 4 grams, a similar sized paperboard cup weighs about 12 grams, a difference of 8 grams.[26] Thus, for every 100 million one-use cups used and landfilled, if all cups were PS the total amount landfilled would be 440 tons, and for all paper cups, the total amount landfilled would be 1,320 tons.

Polystyrene Environmental and Health Impacts

There are three key areas discussed in this section: lifecycle impacts, health impacts, and environmental impacts. When compared to many alternatives, the lifecycle impacts of PS products that are properly disposed or recycled are positive, and should be recognized. The health impacts of PS have been controversial at times, but appear to be minimal. The primary environmental impact of PS relates to litter and improperly disposed PS, particularly in the marine environment. This is the key issue of concern for PS, and should be addressed in future industry deliberations and policy-making. Each of these areas is summarized briefly, below.

Life-Cycle Impacts

PS protective packaging is light, strong, and effective in protecting a wide range of products. It reduces breakage and the total weight of waste disposed as compared to other alternatives. PS containers used to ship produce and fish provide insulation, and have been shown to keep food fresher than typical wood or cardboard containers. One study found that EPS boxes were more effective than corrugated cardboard boxes for shipping fresh fruits and vegetables in controlling acidity, maintaining solid content, reducing pigment loss, reducing vitamin loss, and extending freshness.[27]

A life cycle analysis comparing foam PS and bleached paperboard plates, cups, and hinged containers found that the PS containers require 30 percent less energy than the paper containers, contributed 29 percent more to solid waste volume, have 46 percent lower atmospheric emissions, and contributed 42 percent less waterborne wastes.[28] Similarly, Martin B. Hocking, at the University of Victoria, Department of Chemistry found that with respect to overall energy costs during fabrication and use, reusable cups have similar energy consumption to one-use PS foam cups after 500 uses.[29] Paper cups were found to have the lowest energy consumption. Hocking also notes that paper cups result in additional chemical use and emissions as compared to PS cups.[30]

These life-cycle studies highlight the fact that polystyrene has many benefits, and in some cases is superior in a variety of ways over alternative products. As long as PS is used appropriately and reused, recycled, or disposed of properly, it appears to have net positive impacts. The one significant area of concern, and potential high costs arise, is when PS products are disposed of improperly – either littered, or tipped, or blown out of overflowing trash receptacles. These problems are discussed below.

Health Impacts

The primary health issue of concern as it relates to PS is the migration of the monomer used in the production of PS, styrene, from PS food containers into food and drinks. Styrene is one of the most widely used organic chemicals, used in the production of thousands of products including containers, cars, boats, computers, medical equipment, and safety equipment.[31] Styrene is derived from petroleum and natural gas, occurs naturally in some plants and foods, and is also approved by the FDA for use as a food additive.

Beginning in the late 1970s, some organizations and researchers raised concerns about the migration of styrene from PS food and drink containers.[32] These organizations cited studies showing that styrene migrates from containers into foods and drinks, and that styrene residues are found in human fat and breast milk. There were concerns about styrene being a potential carcinogen, as well as a neurotoxin. There is still information on the Internet today raising questions about the risks of PS. To these organizations, the safety issue is not resolved, although numerous studies have been conducted that show little or no risk.

Potential migration of styrene from food containers is a minor source of PS. Exposure to styrene occurs from a number of sources, including air (from gasoline combustion and industrial sources), water, cigarette smoke, exposure to waxes and products with styrene, and ingestion (from natural sources, migration, or additives).[33] A number of studies have found small concentrations of styrene in human tissue. These levels of styrene are not associated with negative health impacts. Styrene does not appear to bioaccumulate, and when exposed to high doses, most (90 percent) of styrene is excreted from the body within hours, and from fat within several days. Styrene degrades in the atmosphere, volatizes from water, and is biodegraded by aerobic microorganisms in the soil.[34]

There is inadequate evidence in humans for the carcinogenicity of styrene, and limited evidence of carcinogenicity in experimental animals.[35] Styrene is classified by the International Agency for Research on Cancer as possibly carcinogenic to humans, but it is not classified as a human carcinogen by the American Conference of Governmental Industrial Hygienists.[36] The Harvard Center for Risk Analysis concluded that there was no convincing evidence of human carcinogenicity, but suggested additional research on carcinogenicty in mice.[37]

Styrene is not without health impacts. Styrene has central and peripheral nervous system effects in workers exposed to high levels.[38] Symptoms include headache, fatigue, weakness, depression, and a feeling of drunkenness. Symptoms are alleviated when no longer exposed to styrene. Styrene can also cause eye and mucous membrane irritation, and there are concerns about potential hearing loss with long-term high-level exposure. These impacts are found at significantly higher exposure levels than ambient styrene concentrations.

The Harvard Center for Risk Analysis study found "no cause for concern for exposures from contact with products made with styrene, including food contact products such as packaging and serving containers." The National Institute of Health Toxnet database, which includes over 100 pages of research summaries on styrene, supports these findings.

Because styrene has been shown to migrate from PS containers in small amounts, it is prudent to follow appropriate procedures to minimize the migration. For example, food and drinks should not be microwaved in PS containers – instead use containers intended for microwave use. The plasticsinfo.org web page, a service of the American Plastics Council, notes: "Most cold-food packages – such as margarine tubs, cottage cheese containers, and foam meat trays – are not intended for microwave use."[39]

Environmental Impacts

The most significant environmental impact from PS results from the improper disposal (littering) of PS containers. Polystyrene is a significant component in coastal litter collection programs and monitoring studies. In the 1999 U.S. Coastal Cleanup (a one-day nationwide cleanup program held each fall), foamed PS pieces were fourth in all material collected, over 5 percent of the total number of pieces collected.[40] Only cigarette butts, plastic pieces, and plastic food bags and wrappers were higher than foam pieces. As shown in Table 7, the nine categories of foam, including fast food containers, cups, egg cartons, and plates accounted for 11 percent of the total number of pieces collected, a total of 461,124 pieces of foam products.[41] California accounted for 20 percent, by weight, of the total tonnage of material collected in the U.S. in 1999. A study conducted from August to September 1998, quantified California beach debris from 43 random sites from Seal Beach to San Clemente.[42] The most abundant item was pre-production plastic pellets, followed by foamed plastic, shown in Table 8.[43]

Table 7
U.S. Coastal Cleanup Results – Foam, 1999

	Foamed Plastic	Pieces	Foam %	Total %
1	Buoys	13,609	3.0%	0.3%
2	Cups	84,652	18.4%	2.0%
3	Egg cartons	3,503	0.8%	0.1%
4	Fast food containers	26,880	5.8%	0.6%
5	Meat trays	8,688	1.9%	0.2%
6	Packaging materials	48,329	10.5%	1.2%
7	Foamed PS pieces	214,960	46.6%	5.1%
8	Plates	17,997	3.9%	0.4%
9	Other foamed plastic	42,506	9.2%	1.0%
	Total Foamed	461,124	100.0%	11.0%
	Total Pieces	4,191,169		

Table 8
Estimated Total Abundance and Weight of Trash on Orange County Beaches
August to September, 1999

	Debris Type	Number	Weight (pounds)
1	Pre-production plastic pellets	105,161,101	4,780
2	Foamed plastics	742,296	1,526
3	Hard plastics	642,020	7,910
4	Cigarette butts	139,447	344
5	Paper	67,582	870
6	Wood	27,919	4,554
7	Metal	23,500	3,015
8	Glass	22,195	1,944
9	Rubber	10,742	817
10	Pet and bird droppings	9,388	17
11	Cloth	5,949	1,432
12	Other	10,363	401

Polystyrene and other plastics in the marine environment result in significant problems for wildlife, as well as impacting tourism. Over 265 species of marine and coastal wildlife are threatened by entanglement, smothering, and interference with digestive systems.[44] Ingestion of polystyrene pieces and other plastics, which look like food to many species, results in reduced appetite, reduced nutrient absorption, and starvation. Marine debris creates problems for fisherman and recreational boaters, particularly when plastics get into boat engines and cause damage. Scientists have also identified new areas of concern related to floatable plastics litter, including adsorption of toxic substances in sea water to plastic resin pellets and the transportation of invasive species such as barnacles, mollusks, sea worms, and corals to islands and other sensitive ecosystems, traveling on plastic litter "boats".[45] Finally, with over 1,000 miles of coastline, maintaining the quality of California's beaches and coast is important for the State's tourism industry.

Polystyrene is of particular concern because it is light, floats, and is highly visible. In addition, PS foam breaks into small pieces, increasing the chance of ingestion by wildlife and increasing the difficulty and cost of collection. The nature of the material's use, for disposable one-use consumption, often at fast food restaurants, may increase the likelihood that the material will be disposed of improperly. Also, because of it's light weight, even properly disposed containers in full trash receptacles may end up blowing away and becoming litter.

PS is not the only material entering storm drains as trash, but because of these characteristics and it's high visibility, PS is of particular concern in storm drains. PS is one of the trash items most commonly found in storm drains in Los Angeles County,[46] and thus became a focus of those cities' efforts to eliminate trash in storm drains over the next 13 years as part of the TMDL requirements. An estimated 1/5 to 1/3 of the trash at one location that accumulates trash from Long Beach and Signal Hill storm drains in the summer was recently estimated to be white PS cups and clam shell containers (followed by plastic water bottles and plastic bags).[47]

The high costs of litter cleanup and collection are a significant economic externality of plastics, especially PS, that should be addressed in public policy and/or industry-led initiatives. A Seattle Times article estimated the cost of collecting litter at $1.11 per pound.[48] In Orange County, it costs $350,000 for one summer's litter collection on 6 miles of beach.[49] The total litter collection costs for cleaning up 19 beaches along 31 miles in Los Angeles County was over $4 million in 1994. The City of Long Beach and Los Angeles County currently spend about $1 million a year on litter collection in Long Beach Harbor, the mouth of the Los Angeles River.[50] Using a figure of about 3,000 tons collected in 1998-1999, the collection cost is over $300 per ton. The Los Angeles County Department of Public Works also contracts out the cleaning of over 75l,000 catch basins for a total cost of over $1 million a year.[51]

While significant, these costs are far lower than the estimated costs of compliance with the trash TMDL for the Los Angeles River and other nearby watersheds. Retrofitting the 150,000 catch basins in the Los Angeles River watershed with inserts to trap litter will cost an estimated $120 million in capital costs over the next ten years, and $60 million a year in operation and maintenance costs once all the inserts are installed.[52] The most expensive option, low capacity vortex separation systems, have a total capital cost of $945 million, and annual operation and maintenance costs of $148 million. Large capacity vortex separation systems have capital costs of $322 million, but lower operation and maintenance costs of $7.4 million a year. Efforts to enforce litter laws is estimated to cost less than $1 million per year.[53]

Polystyrene Recommendations

SB 1127 requests that the CIWMB make recommendations for source reducing, reusing, recycling, and diverting PS from California's landfills. While each plastic resin type has its own unique characteristics and issues, most of the problems and benefits of plastics discussed in the plastics white paper executive summary (volume 1), apply to all plastics, including polystyrene. Because plastic issues are so deeply interrelated, it is difficult to single out a specific resin or product for policy purposes. The recommendations included in this report, and the recommendations in the plastics white paper should be integrated – while there are specific issues and concerns with polystyrene that are addressed independently in this report, PS should definetly be part of the broader plastic discussions.

PS should not be singled out from other plastic resins for the purposes of increasing PS diversion, or the broader white paper goal of optimizing plastics use, recycling, and disposal in California. Statewide efforts to improve the collection and recycling of plastics, to support and promote technological advances in plastics recycling and conversion, and to develop collaborative solutions to promote and fund plastics resource conservation should include and involve polystyrene, along with other plastic resin types.

Increasing Diversion

While PS in landfills have relatively little impact on landfill space or collection costs, increasing the amount of PS diverted can have an indirect impact on reducing the amount of PS that is improperly disposed. The options below to promote the source reduction, collection, reuse, and recycling of PS will all lead to increased diversion of PS from California's landfills. Descriptions and discussion of the options listed in this report are provided in the plastics white paper, volume 1, executive summary, pages 31 to 51. To the extent that new technologies, particularly conversion, provide alternatives to landfill disposal for PS, the following policy options could increase PS diversion:

- Provide technical support for new technologies
- Provide financial support for new technologies
- Evaluate new technologies
- Support collection for new technologies
- Support conversion technologies
- Conduct forums and workshops for new technologies
- Work with agencies and industry advisors to support technologies
- Conduct technology education symposia for cities and counties
- Work with CPCFA and TCA to fund technologies
- Streamline permitting with Cal/EPA.

Source Reduction

The PS industry has made significant advances in source reduction of PS since the 1970s. An estimated 204,000 tons of PS packaging and disposables were source reduced in 1997 by using resins more efficiently.[54] Specific products have been source reduced between 2 and 25 percent per unit. Foamed PS itself is a very source reduced material, consisting of at least 90 percent air. According to industry experts, there are few opportunities to further reduce foamed PS without impacting the performance of the product or packaging. Thermoformed PS, such as clear crystal PS clamshells, which are relatively new to the packaging industry, have greater potential for source reduction, and industry will continue to reduce the amount of material used, particularly as it competes for market share with other resins in similar containers. One recommendation from volume 1 specifically addresses source reduction and applies to PS:

- Develop measurement methods and credits for source reduction.

Reuse

The Plastic Loosefill Council estimates that approximately 20 to 30 percent of all loose fill is reused. The loose fill program is a good example of reuse, the benefits of reducing the amount of material landfilled, and the costs of purchasing foam peanuts. Reuse of other PS products include pallets and dunnage, insulated shipping boxes, insulated shippers for radioactive materials, test tube trays, auto parts trays, ice chests and coolers. These products are reused between 2 to 35 times.[55] The CIWMB could promote and support the Plastic Loosefill Council's program, as well as other PS reuse efforts through the following policies:

- Initiate a Plastics Recycling Council
- Conduct an aggressive advertising campaign
- Implement design for recycling/reuse approval, awards
- Develop and publicize list of recycled content, reused, and other environmentally positive products.

Recycling

Efforts to increase PS recycling could take a number of forms. Given the high costs of collecting and processing food service PS, further efforts in this area should be limited. Rather, industry, state and local governments, recyclers, and retailers should work to increase recycling at the commercial level for EPS foam packaging, as well as other PS recycling. The EPS industry has made significant efforts over the last ten years to improve EPS recycling, sometimes with frustrating results. EPS recycling efforts would likely be more effective with a coordinated approach between industry, recyclers, retailers and local governments. These initiatives should be part of the plastics white paper recommendations to improve the collection and recycling of plastics in general:

- Address AB 939 incentives
- Legislate changes in AB 939 definitions
- Increase market development support for plastics

- Provide support for collection and processing
- Develop and publicize collection and processing best practices
- Implement loans/grants for equipment
- Develop and publicize plastic quality standards
- Expand Buy Recycled, procurement programs
- Implement positive incentives for recycled content (open- and closed-loop)
- Support EPS collection from small/medium sized commercial generators (similar to the recommendations for film plastics in volume 1)
- Support or require take-back locations for EPS during holidays when household generation rates are high.

Composting/Biodegradable Products

Biodegradable plastics are a technological innovation that hold promise as a replacement for PS foam food service products – cups, clamshells, and plates. There are several companies that have developed, or are developing biodegradable alternatives. Companies such as McDonald's are testing products. While there are still concerns that these materials are not currently competitive in terms of price, or some quality characteristics, they appear to hold significant promise. The value of biodegradable food service packaging is twofold: 1) institutional users can incorporate the packaging into food composting collection systems, and 2) if the material is improperly disposed or blows out of trash cans, the negative impact on wildlife and storm drain systems is eliminated when the material biodegrades. Using biodegradable food service will not eliminate litter problems, and the material will not biodegrade in modern landfills, but it could potentially reduce the negative impacts of these materials, and should be included as part of a broader anti-litter effort. In addition to the technology options above, the following specific policy will help promote biodegradable foam food packaging as an alternative to foam PS:

- Implement government stimulation for biodegradables.

Reducing Discards and Litter

The issue of reducing PS litter should be addressed through coordinated, facilitated discussions between all involved parties, including the LARWQCB, the State Water Quality Control Board, affected local governments, PS industry, fast food industry, restaurants and institutional users, biodegradable food service industry, Keep California Beautiful, environmental groups, community groups, and others. The solution to the problem will likely include a number of approaches that will require the support and participation of all involved. Possible solutions include expanded anti-litter education, increased litter law enforcement, expanded beach cleanup programs, expanded street sweeping, storm water system improvements (nets, inserts, etc.), promotion and increased use of biodegradable foam food service containers, and other alternatives to be developed. Specific recommendations from volume 1 that apply to this issue include:

- Conduct DOC litter study
- Increase litter education
- Enforce litter violations
- Initiate a collaborative industry process.

The CIWMB, LARWQCB, PS industry, Los Angeles County cities, and other interested groups began a dialogue in July 2002 to consider ways to meet the trash TMDL that was the original impetus for the bill that later required this report on PS. The need to address this specific policy issue far outweighs any other potential concerns or problems related to polystyrene. PS is a minor component in our landfill, has been source reduced, and there are successful industry-led initiatives in place to reuse and recycle PS. While these efforts should be further encouraged, the critical issue that must now be addressed as it relates to PS is reducing the amount of litter that is entering storm drain systems. While Los Angeles is the first area impacted by the TMDL requirements, it is only the start of a process required by the Clean Water Act to improve water quality – other coastal and inland areas will likely follow over the next several years.

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